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GROUND MOTION DATA FOR INTERNATIONAL COLLIDER MODELS

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The proposed location for the International Linear Collider (ILC) in the Americas region is Fermilab in Batavia Illinois. If built at this location the tunnels would be located in the Galena Platteville shale at a depth of 100 or more meters below the surface. Studies using hydro static water levels and seismometers have been conducted in the MINOS hall and the LaFrange Mine in North Aurora Illinois to determine the level of ground motion. Both these locations are in the Galena Platteville shale and indicate the typical ground motion to be expected for the ILC. The data contains both natural and cultural noise. Coefficients for the ALT law are determined. Seismic measurements at the surface and 100 meters below the surface are presented.

1.1 Introduction

The proposed location for the International Linear Collider in the Americas region is at Fermilab in Northern Illinois. The preferred depth is 100 or more meters below the surface in the Galena Platteville dolomite. Fermilab and Budker institute have been collaborating on Hydro Static Level systems to measure ground motion for many years. Two of the current systems are in the near MINOS hall on the Fermilab site and the LaFrange (formerly Conco Western [1]) mine in North Aurora Illinois). Both systems are in the Galena Platteville dolomite. Both systems use Budker institute designed and produced HLS systems to measure the change in floor level. Understanding ground motion due to natural and cultures sources are important for modeling the ILC accelerators and storage rings.

2 Apparatus

The MINOS system has 4 HLS sensors and the LaFrange Mine has 6 sensors. In both systems the sensors are spaced 30 meters apart. This is similar to the quadrupole spacing proposed for the ILC (37.956 meters). A sensor consists of a stainless steel pool connected with 12.7 mm ID polyethylene tubing to adjoining pools. In the body of the pool there is a temperature sensor that records the water temperature and allows for corrections to be made for expansion due to temperature changes. Each pool sits on a plate with adjustable legs to allow for leveling of each sensor relative to the others.

On top of the pool is the sensor and electronics. The sensor measures the capacitance of the gap between the sensor face and the top of the water. The sensor is heated to prevent condensation; this would interfere with the precision of the measurements. Each sensor has been calibrated before installation. The gap measurement is accurate to 1 micro meter over a range of 10 mm.

A power and data cable daisy chains between each sensor. The data is read out through a National Instruments card into a PC. Software reads out the data at 1 minute (maximum read out of 100 hertz) and stores the data for later analysis. Both systems are checked every business day to ensure the sensors and computers are functioning. At the end of every month data taking is automatically stopped and re started. A reset pulse is sent out to each sensor in case a software hang occurred. Figure 1 shows a pool and sensor.

The MINOS hall system became operational in December of 2005 and the LaFrange Mine was rebuilt and became operational in September of 2006.

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Figure 1: Budker HLS sensor

With few exceptions for computer hangs there are data for every minute of every month since then. These data are available via a Fermilab data base. The data base is updated every month. The data base is available at http://rexdb01.fnal.gov:8081/ilc/ILCGroundApp.py/index The data is timed stamped in one minute intervals using Central time. All levels are in micro meters, temperatures are in degrees C and pressure is in kilo Pascal.

3 Long Term Trends

Data for both systems were compressed by doing a ten minute average of levels and temperatures. This allowed for time plots and Fast Fourier Transforms (FFTs) to be done on the data to reveal trends in natural and cultural noise. Figure 2 is a plot of the difference between 2 sensors 90 meters apart in the MINOS hall for the month of January 2006.

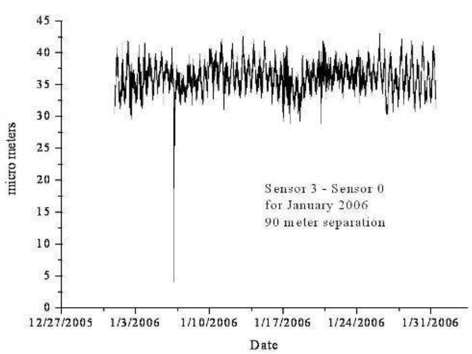

Figure 2: Differences in two sensors 90 meters apart at the MINOS hall for Jan 06

The fast sine wave is due to tidal motion this has a period of 12.4 hours. There is a slower sine wave with a period of 1 week these are the spring and neap tides caused by the relative phases of the sun and moon. The spike that occurs in the first week is due to monthly sump pump testing. There are two electric sump pumps that drain water from the sump pit. The water is the pit varies from a maximum of 75% full to 25% full. As a back up there is a diesel powered sump pump that is run for 30 minutes each month. This test fully drains the sump pit thereby causing a tilt in the floor. After the test is finished the floor tilts back to it nominal position. Figure 3 shows an expanded view of the sump pump test.

Figure 4 is the same data for December 2005 through March of 2007. The sump pump tests are visible as sharp lines the dip that occurs in the summer months of 2006 may be seasonal more data is required to evaluate this. Figure 5 is a similar plot for the LaFrange data. This is a ten minute average of the difference between two sensors 150 meters apart. There is a clear yearly variation in the motion of the floor.

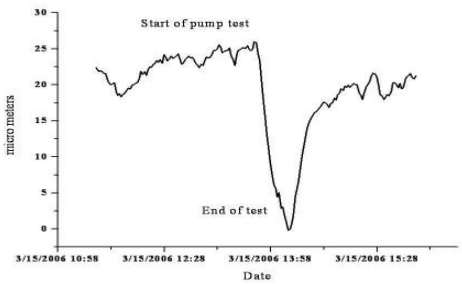

Figure 3: Tilt in floor due to sump pump test

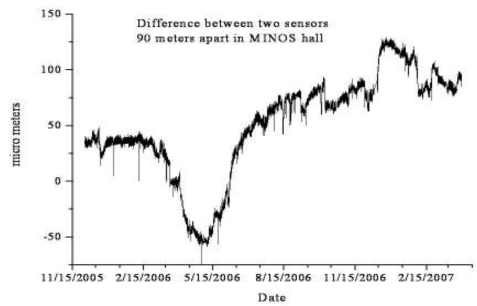

Figure 4: Differences in two sensors 90 meters apart at the MINOS hall for Dec 05 to Mar 07

Figure 6 is a Fast Fourier transform of the MINOS data. The there is a clear spike at 12.4 hours from the tidal motion and a peak at the 28 day point for the sump pump test.

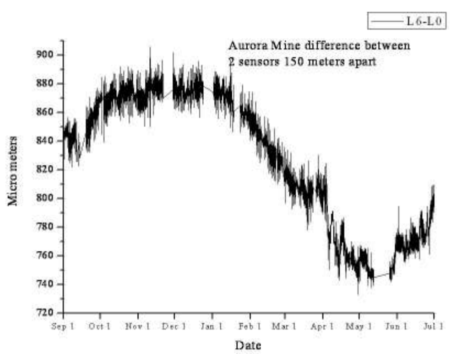

Figure 5 Difference between two sensors 150 meters apart in LaFrange mine

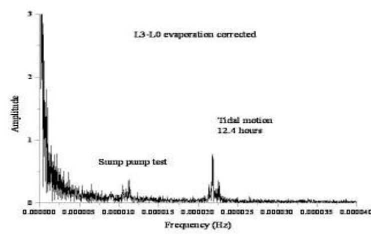

Figure 6: shows the FFT for the MINOS data

4 ATL Law

The ATL law was originally proposed in 1991[2 & 3] to describe the relative displacement between two distant ground points. The empirical rule states that the relative displacement dX of two points at distance L apart grows in time T as

$$< dX^2 > = 2ATL$$

Where A is on the order of $10^{-5\pm1}$ $\mu m^2/s\text{-}m$ and depends on location. The MINOS and LaFrange mine data can be used to determine this constant for the Fermilab area. The process is to first calculate the second differences for the system. In the case of the MINOS data there are four sensors L0 through L3 two second differences can be calculated these are;

$$SD012 = L0\text{-}2L1\text{-}L2$$
$$SD123 = L1\text{-}2L2\text{-}L3$$

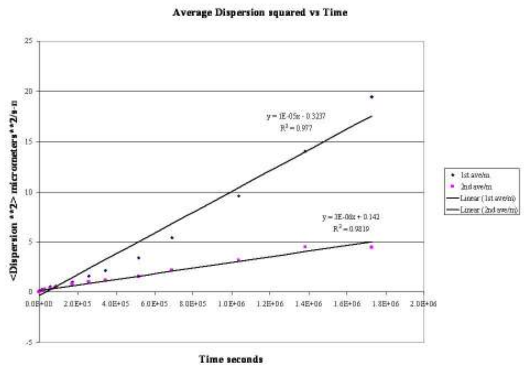

Figure 7 Time vs. average of dispersion yielding the constant for A

Where L0, L1, L2 and L3 are the levels recorded for each sensor in micrometers. The dispersion is then calculated by subtracting the second differences for various time increments ranging for 1 minute (the smallest time value) up to several weeks.

$$D\_SD012 = SD012(t) - SD012(t+i)$$
$$D\_SD123 = SD123(t) - SD123(t+i)$$

These values are then squared and average for each time increment. The slope of a plot of the means square dispersion versus time yields twice the value of A.

Figure 7 shows data for November 2006 taken in the MINOS hall. The value of A is 5 to 1.5 10^{-6} μm^2/s-m.

5 Seismic Motion

Two Budker seismometers one for vertical and one for horizontal were used to measure ground motion in the range of 1 hertz to 200 hertz. Base line measurements were made at the surface on a concrete slab similar measurements were made in the MINOS near hall at a depth of 100 meters below the surface. Figure 8 and 9 show the activity for the surface measurements. There are screw compressors at the Central Helium Liquefier that generate at 4.6 hertz signal all over the site.

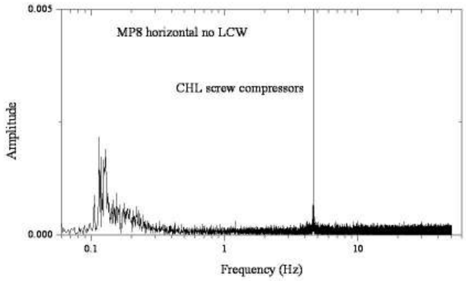

Figure 8 horizontal motions on surface at Fermilab

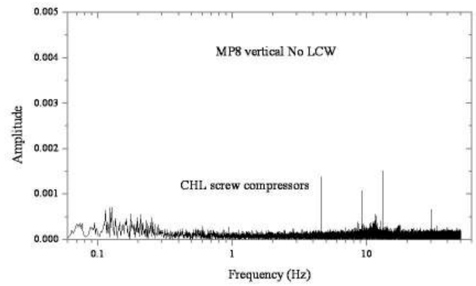

Figure 9 vertical motions on surface at Fermilab

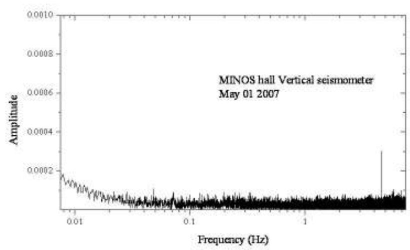

Figure 10 vertical motions 100 meters below surface

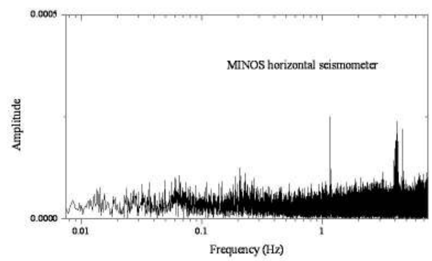

Figure 11 horizontal motions 100 meters below surface

It is clear that there is some attenuation of the culture noise. This is important for the ILC in that many sources of cultural noise can not be eliminated.

6 Conclusions

Data has been collected for over 14 months in a HLS system installed at the depth that the ILC would be built in Illinois. The value of the constant A in the ATL law has been determined to be 5 to 1.5 10^{-6} μm^2/s-m. In addition a parameterization for tidal motion has been presented. These can be used in modeling the ILC. Cultural seismic noise is attenuated with depth.

7 References

[1] V Shiltsev et al "VLHC/NLC "Slow Ground motions studies in Illinois" PAC 2001
[2] B.A. Baklavkov et al "Investigation of Correlation and Power Characteristics of Earth Surface Motion in the UNK Complex Region" PAC 1991
[3] B.A. Baklalvo et al "Study of Seismic Vibrations for the VLEPP Linear Collider" Tech Phys v.38 p 894